US009147653B2

(12) **United States Patent**
Yuan et al.

(10) **Patent No.: US 9,147,653 B2**
(45) **Date of Patent: Sep. 29, 2015**

(54) **METHOD FOR OFF-GRID ROUTING STRUCTURES UTILIZING SELF ALIGNED DOUBLE PATTERNING (SADP) TECHNOLOGY**

(71) Applicant: **GLOBALFOUNDRIES Inc.**, Grand Cayman (KY)

(72) Inventors: **Lei Yuan**, Cupertino, CA (US); **Jongwook Kye**, Pleasanton, CA (US); **Harry Levinson**, Saratoga, CA (US)

(73) Assignee: **GLOBALFOUNDRIES INC.**, Grand Cayman (KY)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/513,834**

(22) Filed: **Oct. 14, 2014**

(65) **Prior Publication Data**

US 2015/0028489 A1 Jan. 29, 2015

Related U.S. Application Data

(62) Division of application No. 13/766,141, filed on Feb. 13, 2013, now Pat. No. 8,921,225.

(51) **Int. Cl.**

H01L 23/498	(2006.01)
H01L 21/308	(2006.01)
H01L 23/50	(2006.01)
H01L 21/768	(2006.01)
H01L 21/033	(2006.01)
H01L 21/311	(2006.01)
H01L 23/528	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 23/49838*** (2013.01); ***H01L 21/0337*** (2013.01); ***H01L 21/308*** (2013.01); ***H01L 21/31144*** (2013.01); ***H01L 21/76816*** (2013.01); ***H01L 21/76838*** (2013.01); ***H01L 23/50*** (2013.01); *H01L 23/528* (2013.01); *H01L 2924/0002* (2013.01)

(58) **Field of Classification Search**

CPC H01L 23/49838
USPC 257/773, E21.586
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0113393	A1	5/2011	Sezginer	
2012/0180014	A1	7/2012	Fang et al.	
2014/0024209	A1 *	1/2014	Jung et al.	438/595
2014/0057436	A1	2/2014	Chen et al.	
2014/0159164	A1 *	6/2014	Woo et al.	257/401

FOREIGN PATENT DOCUMENTS

TW	200629093	A	8/2006
TW	200629097	A	8/2006

OTHER PUBLICATIONS

Taiwanese Office Action for related Taiwanese Patent Application No. 102134707 dated Apr. 9, 2015, 7 pages.

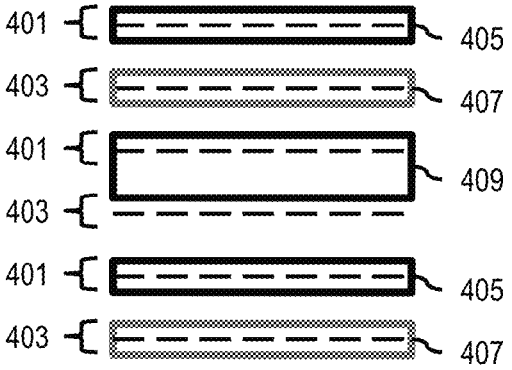
* cited by examiner

Primary Examiner — Mamadou Diallo
(74) *Attorney, Agent, or Firm* — Ditthavong & Steiner, P.C.

(57) **ABSTRACT**

A method for efficient off-track routing and the resulting device are disclosed. Embodiments include: providing a hardmask on a substrate; providing a plurality of first mandrels on the hardmask; providing a first spacer on each side of each of the first mandrels; providing a plurality of first non-mandrel regions of the substrate being separated from the first mandrels and between two of the first spacers, each of the first mandrels, first non-mandrel regions, and first spacers having a width equal to a distance; and providing a second mandrel having a width of at least twice the distance and being separated from one of the first non-mandrel regions by a second spacer.

20 Claims, 5 Drawing Sheets



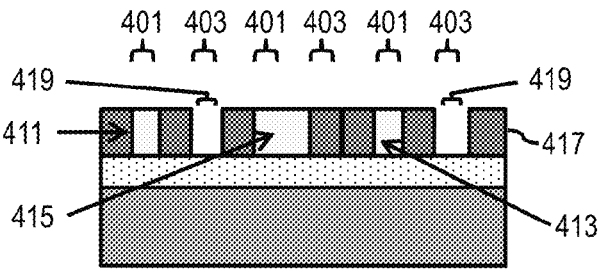


FIG. 1A

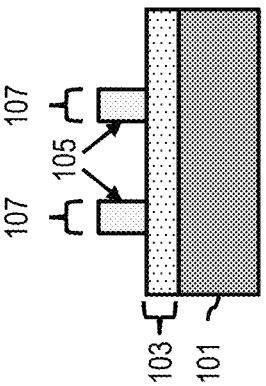


FIG. 1B

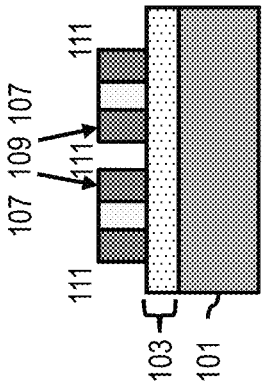


FIG. 1C

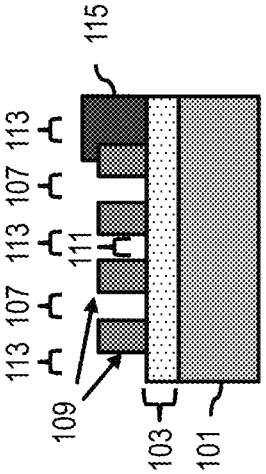


FIG. 1D

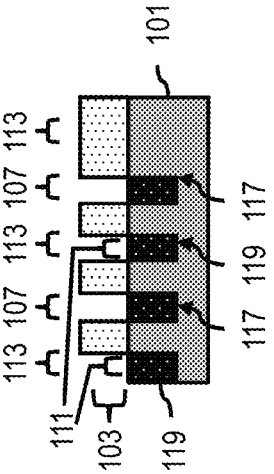


FIG. 1E

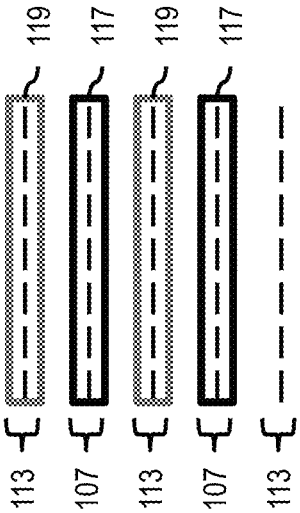


FIG. 2A

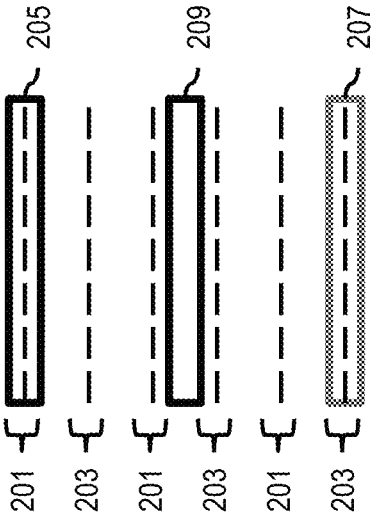


FIG. 2B

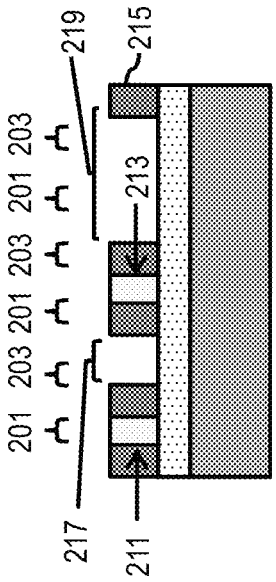


FIG. 2C

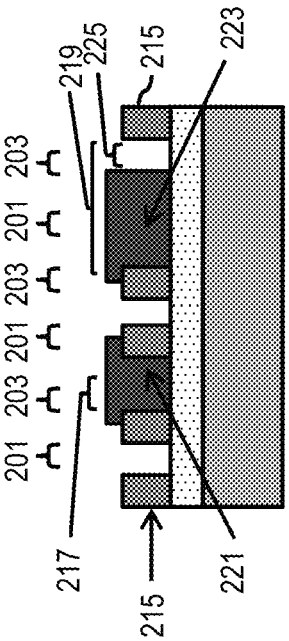


FIG. 2D

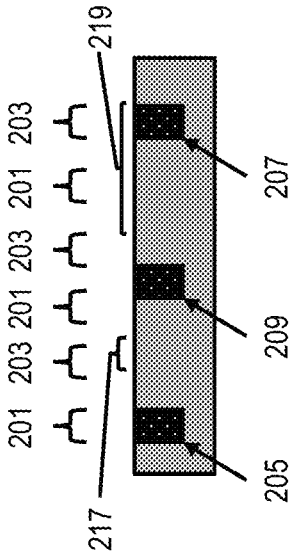


FIG. 3A

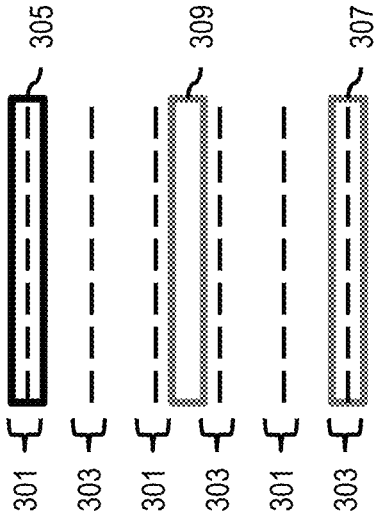


FIG. 3B

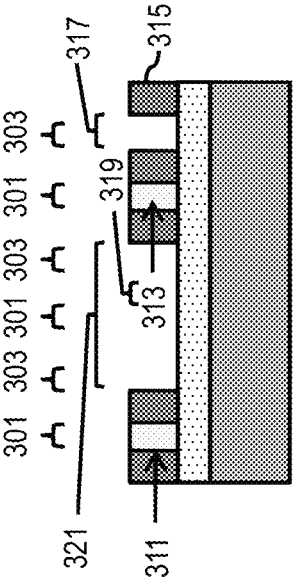


FIG. 3C

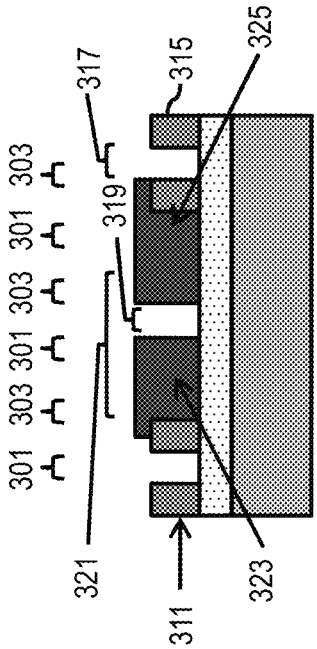


FIG. 3D

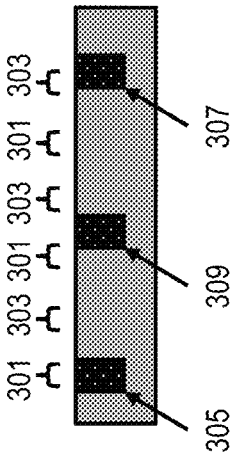


FIG. 4A

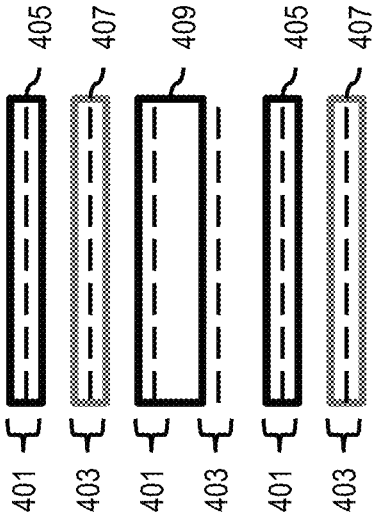


FIG. 4B

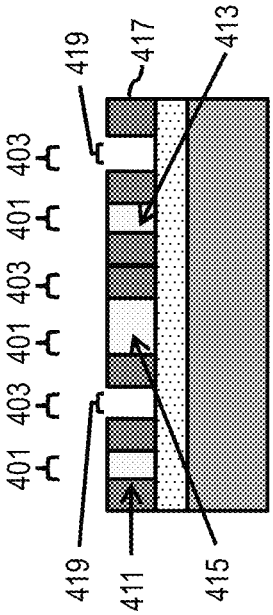


FIG. 4C

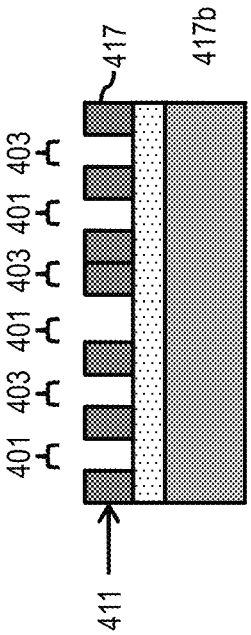


FIG. 4D

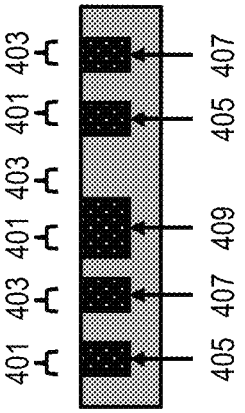


FIG. 5A

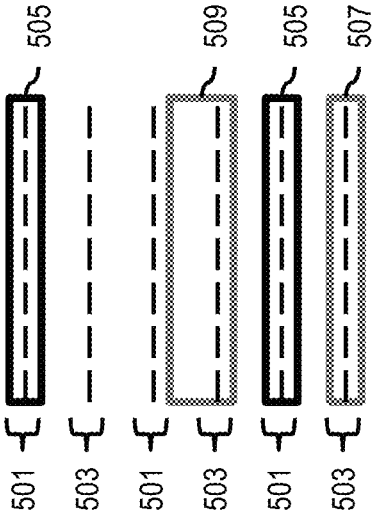


FIG. 5B

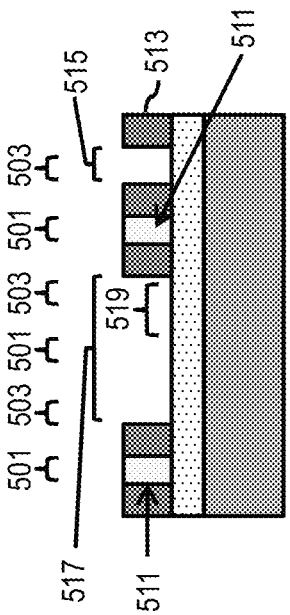


FIG. 5C

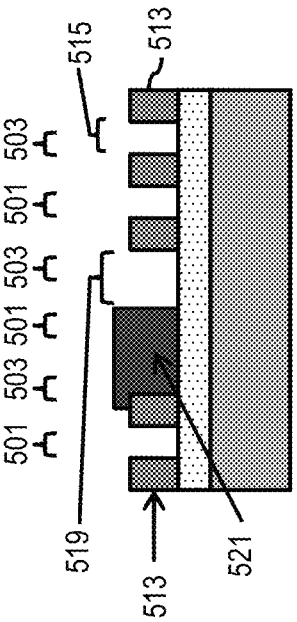
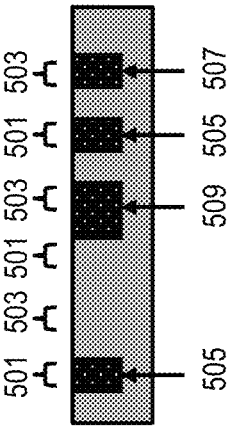


FIG. 5D



METHOD FOR OFF-GRID ROUTING STRUCTURES UTILIZING SELF ALIGNED DOUBLE PATTERNING (SADP) TECHNOLOGY

CROSS REFERENCE TO RELATED APPLICATION

This application is a Divisional of U.S. application Ser. No. 13/766,141, filed Feb. 13, 2013 the content of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present disclosure relates to a fabrication of metal structures. The present disclosure is particularly applicable to fabrication of off-grid metal structures in integrated circuits (ICs) utilizing SADP technology.

BACKGROUND

In a fabrication of metal routes, particularly a fabrication of metal routes using SADP technology, metal routes are typically placed on one of many pre-determined gridded routing tracks. Such routing tracks are frequently spaced to efficiently utilize space on an IC layout and to obtain adequate performance, reliability, and manufacturability of the resulting device. However, off-grid routing may become necessary to allow flexible pin access, redundant via/via bar insertion, and metal transition. Unfortunately, traditional methods place off-grid metal islands between routing tracks, resulting in inefficient use of IC layouts utilizing SADP technology. For instance, some methods require four tracks for insertion of a single off-grid metal island between routing tracks.

A need therefore exists for methodology enabling efficient off-track routing for ICs utilizing SADP technology, and the resulting device.

SUMMARY

An aspect of the present disclosure is a method of fabricating a semiconductor device having an off-grid metal structure preventing use of two tracks by, inter alia, providing a mandrel having a width of at least a distance between pre-determined gridded routing tracks.

An aspect of the present disclosure is a method of fabricating a semiconductor device having an off-grid metal structure preventing use of three tracks by, inter alia, providing a non-mandrel region having a width of at least a distance between pre-determined gridded routing tracks.

A further aspect of the present disclosure is a device having, inter alia, a metal route positioned on one vertical position of equally spaced vertical positions (e.g., pre-determined gridded routing tracks) and extending vertically onto at least a midpoint between the one vertical position and another one of the vertical positions (e.g., an adjacent track).

Additional aspects and other features of the present disclosure will be set forth in the description which follows and in part will be apparent to those having ordinary skill in the art upon examination of the following or may be learned from the practice of the present disclosure. The advantages of the present disclosure may be realized and obtained as particularly pointed out in the appended claims.

According to the present disclosure, some technical effects may be achieved in part by a method including: providing a hardmask on a substrate; providing a plurality of first mandrels on the hardmask; providing a first spacer on each side of each of the first mandrels; providing a plurality of first non-mandrel regions of the substrate being separated from the first mandrels and between two of the first spacers, each of the first mandrels, first non-mandrel regions, and first spacers having a width equal to a distance; and providing a second mandrel having a width of at least twice the distance and being separated from one of the first non-mandrel regions by a second spacer and/or providing a second non-mandrel region having a width of at least twice the distance and being adjacent to at least one of the first spacers or a third spacer of a third mandrel and separated from one or more block masks.

Some aspects include a method, wherein the second mandrel is provided, the method further including: providing a fourth mandrel on the hardmask; and providing one or more spacers between the second and fourth mandrels, the one or more spacers covering an entire upper surface of the hardmask between the second and fourth mandrels. Additional aspects include providing the fourth mandrel with a width of at least the distance, and the one or more spacers with a width of twice the distance. Some aspects include a method wherein, the one or more spacers include a fourth spacer adjacent to the second mandrel and a fifth spacer adjacent to the fourth mandrel, each of the fourth and fifth spacers having a width equal to the distance. Further aspects include a method, wherein the second non-mandrel region is provided, the method further including providing one of the block masks between the second non-mandrel region and one of the first or third spacers, the block mask preventing etching of portions of the hardmask covered by the one block mask. Additional aspects include: providing the third mandrel region having a width of at least the distance and with the third spacer having a width of the distance; and providing the one block mask having a width of at least three times the distance. Further aspects include: etching the hardmask, each respective spacer of the first spacers preventing etching of one or more portions covered by the respective spacer; etching, after etching of the hardmask, the substrate, the hardmask preventing etching of portions covered by the hardmask; and forming a metal layer in recesses formed by the etching of the substrate. Some aspects include: removing the first mandrels prior to etching the hardmask, wherein a mandrel metal route is provided in a recess formed by etching a portion of the hardmask formerly covered by one of the first mandrels and a non-metal route is formed in a recess formed by etching the hardmask in one of the first non-mandrel regions.

Another aspect of the present disclosure is a device including: an IC formed on a substrate; a plurality of metal routes extending horizontally on the substrate and placed on one of a plurality of equally spaced vertical positions being separated by a distance; and a metal route of the metal routes positioned on one of the vertical positions and extending vertically onto at least a midpoint between the one vertical position and another vertical position.

Aspects include a second metal route of the metal routes being positioned on a second vertical position of the vertical positions adjacent to the one vertical position. Some aspects include a third metal route of the metal routes being positioned on a third vertical position of the vertical positions being within three vertical positions from the one vertical position, the second and third vertical positions being on opposite sides of the one vertical position. Further aspects include the metal routes being formed by either a mandrel metal or a non-mandrel metal of a SADP technology, wherein metal routes formed by a mandrel metal are separated from each other by at least one vertical position and metal routes formed by a non-mandrel metal are separated from each other by at least one vertical position. Additional aspects include

the third metal route of the metal routes being positioned on a vertical position three vertical positions from the one vertical position when the one metal route is formed by a non-mandrel metal and positioned on a vertical position two vertical positions from the one vertical position when the one metal route is formed by a mandrel metal. Further aspects include the metal routes being within a M1 or M2 layer of the IC. Some aspects include the metal route being connected to another metal layer via a redundant via, a pin access, or a metal transition region. Additional aspects include a device, wherein the distance is a multiple of a critical distance associated with one or more masks fabricating the IC.

Another aspect of the present disclosure is a method including: providing a hardmask on a substrate; providing a plurality of first mandrels on the hardmask; providing a first spacer on each side of each of the first mandrels; providing a plurality of first non-mandrel regions of the substrate being separated from the first mandrels and between two of the first spacers, each of the first mandrels, first non-mandrel regions, and first spacers having a width equal to a distance; providing a second mandrel having a width of at least twice the distance and having a second spacer adjacent to one of the first non-mandrel regions and/or providing a second non-mandrel region having a width of at least twice the distance and being adjacent to at least one of the first spacers or a third spacer of a third mandrel and separated from one or more block masks; removing the first mandrels after providing the first spacers; etching the hardmask, each respective spacer of the first spacers preventing etching of one or more portions covered by the respective spacer; etching the substrate, after etching of the hardmask, the hardmask preventing etching of portions covered by the hardmask; and forming a metal layer in recesses formed by the etching of the substrate.

Aspects include a method, wherein the second mandrel is provided, the method further including: providing a fourth mandrel having a width of at least the distance; and providing one or more spacers between the second and fourth mandrels, the one or more spacers covering an entire upper surface of the hardmask between the second and third mandrels and having a width of twice the distance. Some aspects include a method, wherein the one or more spacers include a fourth spacer adjacent to the second mandrel and a fifth spacer adjacent to the fourth mandrel. Further aspects include a method, wherein the second non-mandrel region is provided, the method further including: providing the third spacer and the third mandrel having widths of at least the distance; and providing one of the block masks between the second non-mandrel region and either the one first spacer or the third spacer, the one block mask having a width of three times the distance and preventing an etching of portions of the hardmask covered by the one block mask.

Additional aspects and technical effects of the present disclosure will become readily apparent to those skilled in the art from the following detailed description wherein embodiments of the present disclosure are described simply by way of illustration of the best mode contemplated to carry out the present disclosure. As will be realized, the present disclosure is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects, all without departing from the present disclosure. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawing and in which like reference numerals refer to similar elements and in which:

FIGS. **1**A through **1**D schematically illustrate sequential steps of forming metal routes on pre-determined gridded routing tracks;

FIG. **1**E schematically illustrates metal routes on pre-determined gridded routing tracks formed using the steps illustrated in FIGS. **1**A through **1**D;

FIG. **2**A schematically illustrates an exemplary off-track mandrel metal route;

FIGS. **2**B through **2**D schematically illustrate sequential steps of forming the exemplary off-track mandrel metal route illustrated in FIG. **2**A;

FIG. **3**A schematically illustrates an exemplary off-track non-mandrel metal route;

FIGS. **3**B through **3**D schematically illustrate sequential steps of forming the off-track non-mandrel metal route illustrated in FIG. **3**A;

FIG. **4**A schematically illustrates an exemplary off-track mandrel metal route in accordance with an exemplary embodiment;

FIGS. **4**B through **4**D schematically illustrate sequential steps of forming the off-track mandrel metal route illustrated in FIG. **4**A in accordance with an exemplary embodiment;

FIG. **5**A schematically illustrates an exemplary off-track non-mandrel metal route in accordance with an exemplary embodiment; and

FIGS. **5**B through **5**D schematically illustrate sequential steps of forming the off-track non-mandrel metal route illustrated in FIG. **5**A in accordance with an exemplary embodiment.

DETAILED DESCRIPTION

In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of exemplary embodiments. It should be apparent, however, that exemplary embodiments may be practiced without these specific details or with an equivalent arrangement. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring exemplary embodiments. In addition, unless otherwise indicated, all numbers expressing quantities, ratios, and numerical properties of ingredients, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term "about."

The present disclosure addresses and solves the current problem of layout inefficiency attendant upon devices utilizing off-track routing structures. In accordance with embodiments of the present disclosure, a mandrel is formed having a width of at least a distance between tracks. Additionally, or alternatively, a non-mandrel region is formed having a width of at least a distance between tracks.

Methodology in accordance with embodiments of the present disclosure includes: providing a hardmask on a substrate; providing a plurality of first mandrels on the hardmask; providing a first spacer on each side of each of the first mandrels; providing a plurality of first non-mandrel regions of the substrate being separated from the first mandrels and between two of the first spacers, each of the first mandrels, first non-mandrel regions, and first spacers having a width equal to a distance; and providing a second mandrel having a width of at least twice the distance and being separated from one of the first non-mandrel regions by a second spacer and/or providing a second non-mandrel region having a width of at least twice the distance and being adjacent to at least one of

the first spacers or a third spacer of a third mandrel and separated from one or more block masks.

Still other aspects, features, and technical effects will be readily apparent to those skilled in this art from the following detailed description, wherein preferred embodiments are shown and described, simply by way of illustration of the best mode contemplated. The disclosure is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

Adverting to FIG. **1**A, a substrate **101** is provided with hardmask **103** and mandrels **105** being placed on mandrel tracks **107**. Next, as illustrated in FIG. **1**B, spacers **109** are formed on each side of each of the mandrels **105**. As shown, the spacers **109** separate mandrels **105** from non-mandrel regions **111** and the mandrels **105**, spacers **109**, and non-mandrel regions **111** have equal widths. The mandrels **105** are removed in FIG. **1**C, resulting in the spacers **109** separating mandrels tracks **107** from non-mandrel tracks **113**. Additionally, a block mask **115** is placed in a non-mandrel track **113**. Next, as shown in FIG. **1**D, mandrel metal routes **117** are formed in regions of the substrate **101** formerly covered by mandrels **105** and non-mandrel metal routes **119** are formed in non-mandrel regions **111**. That is, mandrel metal routes **117** and non-mandrel metal routes **119** are placed in recesses formed by etching exposed portions of the hardmask **103** and into the substrate **101** below those exposed portions. As shown, the spacers **109** and block mask **115** prevent etching of other portions of the hardmask **103** and substrate **101**.

FIG. **1**E schematically illustrates metal routes on pre-determined gridded routing tracks formed using the steps illustrated in FIGS. **1**A through **1**D. As shown, mandrel metal routes **117** are formed on mandrel tracks **107** and non-mandrel metal routes **119** are formed on non-mandrel tracks **113**. Additionally, the block mask **115** has prevented a forming of a non-mandrel metal route **119** on one of the non-mandrel tracks **113**. Block masks (e.g. **115**) may also prevent a forming of mandrel metal routes (e.g., **117**). Further, the mandrel and non-mandrel metal routes **117** and **119**, respectively, have equal widths and are separated by equal distances. Such equal widths and distances may correspond to a critical distance associated with one or more masks for fabrication of an IC. For example, the mandrel and non-mandrel metal routes **117** and **119** may have widths equal to a multiple of a critical distance associated with one or more masks fabricating the IC. Additionally, each pair of mandrel metal routes **117** is separated by at least one non-mandrel track **113** and each pair of non-mandrel metal routes **119** is separated by at least one mandrel track **107**. The metal routes (e.g., **117** and **119**) may be within a M1 or M2 layer of an IC.

FIG. **2**A schematically illustrates an exemplary off-track mandrel metal route. As shown, mandrel tracks **201** and non-mandrel tracks **203** contain mandrel metal route **205** and non-mandrel metal route **207**, respectively, and an off-track mandrel metal route **209** is between one of the mandrel tracks **201** and one of the non-mandrel tracks **203**. As noted above, off-track routes (e.g., **209**) may allow flexible pin access, redundant via/via bar insertion, and metal transition, for instance, by, being connected to another (e.g., upper) metal layer via a redundant via, a pin access, or a metal transition region.

FIGS. **2**B through **2**D schematically illustrate sequential steps of forming the exemplary off-track mandrel metal route illustrated in FIG. **2**A. Adverting to FIG. **2**B, on-track mandrel **211** and off-track mandrel **213** are provided with spacers **215** on each side. A positioning and width of off-track mandrel **213** results in a first region **217** and a second region **219**, each extending beyond non-mandrel tracks **203**. First region **217** has a width greater than a non-mandrel region. Therefore, a block mask would be required to cover the remainder of first region **217** to prevent unwanted subsequent etching of the hardmask and substrate thereunder. However, a block mask has a minimum width that exceeds the difference between the first region and a non-mandrel region. Therefore, a block mask **221** must cover the entire first region **217**, as shown in FIG. **2**C. Similarly, no on-track mandrel (e.g., **211**) can be provided within the second region **219**, as the space between off-track mandrel **213** and an on-track mandrel **211** would not be large enough for a spacer to be formed for each mandrel. However, since the difference between the second region **219** and a non-mandrel region is larger than a block mask minimum width, a block mask may be formed only in a portion of second region **219**, leaving an opening for non-mandrel region **225**.

Adverting to FIG. **2**D, the mandrels are removed, and mandrel metal route **205** is formed in a recess formerly covered by mandrel **211**, non-mandrel route **207** is formed in non-mandrel region **225**, and off-track mandrel metal route **209** is formed in a region formerly covered by off-track mandrel **213**. Therefore, the positioning and width of off-track mandrel **213** prevent a placement on two of the mandrel tracks **201** and on two of the non-mandrel tracks **203**.

FIG. **3**A schematically illustrates an exemplary off-track non-mandrel metal route. As shown, mandrel tracks **301** and non-mandrel tracks **303** contain mandrel metal route **305** and non-mandrel metal route **307**, respectively, and an off-track non-mandrel metal route **309** is between one of the mandrel tracks **301** and one of the non-mandrel tracks **303**.

FIGS. **3**B through **3**D schematically illustrate sequential steps of forming the off-track non-mandrel metal route illustrated in FIG. **3**A. Adverting to FIG. **3**B, on-track mandrels **311** and **313** are provided with spacers **315** on each side. A first non-mandrel region **317** is provided adjacent to one of the spacers **315** of the mandrel **313**. However, the positioning of off-track non-mandrel metal route **309** into non-mandrel region **319** forms a space between spacer **315** and non-mandrel region **319** which would need to be covered by a block mask. However, the space is smaller than a block mask minimum width. Therefore, no mandrel metal route may be formed. As such, mandrel **313** and the spacer closest to region **319** are removed, and block mask **325** is formed as shown in FIG. **3**C. In addition, the space between non-mandrel region **319** and spacer **315** of mandrel **311** precludes formation of an on-track non-mandrel metal route (e.g. **307**) between off-track non-mandrel metal route **309** and mandrel metal route **305**. Therefore, a block mask **323** is formed, as shown in FIG. **3**C.

Adverting to FIG. **3**D, the mandrel is removed, and mandrel metal route **305** is formed in a recess formerly covered by mandrel **311**, non-mandrel route **307** is formed in non-mandrel region **317**, and off-track non-mandrel metal route **309** is formed in non-mandrel region **319**. However, the positioning and width of off-track non-mandrel metal route **309** prevent a placement on two of the mandrel tracks **301** and on two of the non-mandrel tracks **303**.

FIG. **4**A schematically illustrates an exemplary off-track mandrel metal route, in accordance with an exemplary embodiment. As shown, mandrel tracks **401** and non-mandrel tracks **403** contain mandrel metal routes **405** and non-mandrel metal routes **407**, respectively, and an off-track mandrel metal route **409** is positioned on one of the mandrel tracks **401** and extends onto at least a midpoint between the one of the mandrel tracks **401** and one of the non-mandrel tracks **403**. As

shown, the off-track mandrel metal route **409** has a width of twice of a width of each of the mandrel metal routes **405** and the non-mandrel metal routes **407**.

FIGS. **4**B through **4**D schematically illustrate sequential steps of forming the off-track mandrel metal route illustrated in FIG. **4**A, in accordance with an exemplary embodiment. Adverting to FIG. **4**B, on-track first and second mandrels **411** and **413**, respectively, and off-track mandrel **415** are provided with spacers **417** on each side. The off-track mandrel **415** is positioned and sized such that a spacer **417** on one side of the mandrel **415** abuts a boundary of a non-mandrel region **419** and a spacer **417** on the other side abuts a spacer **417** for the second mandrel **413**. As such, no block mask is needed to separate the off-track mandrel **415** from the non-mandrel region **419**. Furthermore, spacers **417** cover an entire upper surface between the off-track mandrel **415** and on-track second mandrel **413**. As such, no block mask is required to cover a region between off-track mandrel **415** and on-track second mandrel **413**. As illustrated in FIG. **4**C, mandrels **411**, **413**, and **415** are removed. Adverting to FIG. **4**D, mandrel metal routes **405** are formed in recesses formerly covered by mandrels **411** and **413**, non-mandrel routes **407** are formed in non-mandrel regions **419**, and off-track mandrel metal route **409** is formed in a region formerly covered by off-track mandrel **415**. As such, the extending of a width of the off-track mandrel **415** allows a positioning of spacers **417** to prevent a forming of an unwanted space between spacers **417** and non-mandrel regions **419**. Thus, no block masks are necessary and the placement of the off-track mandrel **415** only prevents a placement of metal routes on one of the mandrel tracks **401** and on one of the non-mandrel tracks **403**, thereby saving two tracks.

FIG. **5**A schematically illustrates an exemplary off-track non-mandrel metal route, in accordance with an exemplary embodiment. As shown, mandrel tracks **501** and non-mandrel tracks **503** contain mandrel metal routes **505** and non-mandrel metal route **507**, respectively, and an off-track non-mandrel metal route **509** is positioned on one of the non-mandrel tracks **503** and extends onto at least a midpoint between the one of the non-mandrel tracks **503** and one of the mandrel tracks **501**. As shown, the off-track non-mandrel metal route **509** has a width of twice of a width of each of the mandrel metal routes **505** and the non-mandrel metal routes **507**.

FIGS. **5**B through **5**D schematically illustrate sequential steps of forming the off-track non-mandrel metal route illustrated in FIG. **5**A, in accordance with an exemplary embodiment. Adverting to FIG. **5**B, on-track mandrels **511** are provided with spacers **513** on each side. As shown, a spacer **513** of one of the on-track mandrels **511** is adjacent to the non-mandrel region **519**. As such, no block mask is needed to prevent etching of a portion between the non-mandrel region **519** and a spacer **513**. However, region **517** extends beyond the non-mandrel region **519**. As such, a block mask **521** is provided in FIG. **5**C, to form non-mandrel region **519**. Adverting to FIG. **5**D, mandrel metal routes **505** are formed in recesses formerly covered by mandrels **511**, a non-mandrel route **507** is formed in non-mandrel region **515**, and off-track non-mandrel metal route **509** is formed in non-mandrel region **519**. As such, the extending of a width of the non-mandrel region **519** allows use of only a single block mask (e.g., block mask **521**). Thus, the placement and width of the off-track non-mandrel route **509** only prevents a placement on one of the mandrel tracks (e.g. **501**) and on two of the non-mandrel tracks (e.g. **503**), thereby saving a track.

The embodiments of the present disclosure can achieve several technical effects including off-track metal structures preventing a placement on no more than three tracks, resulting in an improved layout efficiency of a resulting design. The present disclosure enjoys industrial applicability in any of various types of highly integrated semiconductor devices, particularly in IC devices utilizing SADP technology.

In the preceding description, the present disclosure is described with reference to specifically exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the present disclosure, as set forth in the claims. The specification and drawings are, accordingly, to be regarded as illustrative and not as restrictive. It is understood that the present disclosure is capable of using various other combinations and embodiments and is capable of any changes or modifications within the scope of the inventive concept as expressed herein.

What is claimed is:

1. A device comprising:
an integrated circuit (IC) formed on a substrate;
a plurality of metal routes extending horizontally on the substrate and placed on one of a plurality of equally spaced vertical positions being separated by a distance; and
a metal route of the metal routes positioned on one of the vertical positions and extending vertically onto at least a midpoint between the one vertical position and another vertical position.

2. The device according to claim **1**, further comprising:
a second metal route of the metal routes being positioned on a second vertical position of the vertical positions adjacent to the one vertical position.

3. The device according to claim **2**, further comprising:
a third metal route of the metal routes being positioned on a third vertical position of the vertical positions being within three vertical positions from the one vertical position, the second and third vertical positions being on opposite sides of the one vertical position.

4. The device according to claim **3**, further comprising:
the metal routes being formed by either a mandrel metal or a non-mandrel metal of a self-aligned-double-patterning (SADP) technology, wherein metal routes formed by a mandrel metal are separated from each other by at least one vertical position and metal routes formed by a non-mandrel metal are separated from each other by at least one vertical position.

5. The device according to claim **4**, further comprising:
the third metal route of the metal routes being positioned on a vertical position three vertical positions from the one vertical position when the one metal route is formed by a non-mandrel metal and positioned on a vertical position two vertical positions from the one vertical position when the one metal route is formed by a mandrel metal.

6. The device according to claim **1**, further comprising:
the metal routes being within a M1 or M2 layer of the IC.

7. The device according to claim **6**, further comprising:
the metal route being connected to another metal layer via a redundant via, a pin access, or a metal transition region.

8. The device according to claim **1**, wherein the distance is a multiple of a critical distance associated with one or more masks fabricating the IC.

9. A device comprising:
a hardmask on a substrate;
a plurality of first mandrels on the hardmask;
a first spacer on each side of each of the first mandrels;
a plurality of first non-mandrel regions of the substrate being separated from the first mandrels and between two

of the first spacers, each of the first mandrels, first non-mandrel regions, and first spacers having a width equal to a distance;

a second mandrel having a width of at least twice the distance and having a second spacer adjacent to one of the first non-mandrel regions and/or providing a second non-mandrel region having a width of at least twice the distance and being adjacent to at least one of the first spacers or a third spacer of a third mandrel and separated from one or more block masks;

wherein the first mandrels are removed after providing the first spacers;

wherein the hardmask is etched and each respective spacer of the first spacers prevents etching of one or more portions covered by the respective spacer;

wherein the substrate is etched after etching of the hardmask, the hardmask preventing etching of portions covered by the hardmask; and

a metal layer in recesses formed by the etching of the substrate.

10. The device according to claim **9**, further comprising:

a fourth mandrel having a width of at least the distance; and

one or more spacers between the second and fourth mandrels, the one or more spacers covering an entire upper surface of the hardmask between the second and third mandrels and having a width of twice the distance.

11. The device according to claim **10**, wherein the one or more spacers comprise a fourth spacer adjacent to the second mandrel and a fifth spacer adjacent to the fourth mandrel.

12. The method according to claim **9**, wherein the second non-mandrel region is provided, the method further comprising:

providing the third spacer and the third mandrel having widths of at least the distance; and

providing one of the block masks between the second non-mandrel region and either the one first spacer or the third spacer, the one block mask having a width of three times the distance and preventing an etching of portions of the hardmask covered by the one block mask.

13. A device comprising:

a hardmask on a substrate;

a plurality of first mandrels on the hardmask;

a first spacer on each side of each of the first mandrels;

a plurality of first non-mandrel regions of the substrate being separated from the first mandrels and between two of the first spacers, each of the first mandrels, first non-mandrel regions, and first spacers having a width equal to a distance; and

a second mandrel having a width of at least twice the distance and being separated from one of the first non-mandrel regions by a second spacer and/or providing a second non-mandrel region having a width of at least twice the distance and being adjacent to at least one of the first spacers or a third spacer of a third mandrel and separated from one or more block masks.

14. The device according to claim **13**, further comprising:

a fourth mandrel on the hardmask; and

one or more spacers between the second and fourth mandrels, the one or more spacers covering an entire upper surface of the hardmask between the second and fourth mandrels.

15. The device according to claim **14**, wherein the fourth mandrel has a width of at least the distance, and the one or more spacers has a width of twice the distance.

16. The device according to claim **15**, wherein the one or more spacers comprise a fourth spacer adjacent to the second mandrel and a fifth spacer adjacent to the fourth mandrel, each of the fourth and fifth spacers having a width equal to the distance.

17. The device according to claim **13**, further comprising:

one of the block masks between the second non-mandrel region and one of the first or third spacers, the block mask preventing etching of portions of the hardmask covered by the one block mask.

18. The device according to claim **17**, wherein the third mandrel region has a width of at least the distance and the third spacer has a width of the distance; and

the one block mask has a width of at least three times the distance.

19. The method according to claim **13**, wherein

the hardmask is etched, and each respective spacer of the first spacers prevents etching of one or more portions covered by the respective spacer;

the substrate is etched after etching of the hardmask, the hardmask preventing etching of portions covered by the hardmask; and

a metal layer formed in recesses formed by the etching of the substrate.

20. The device according to claim **19**, wherein

the first mandrels are removed prior to etching the hardmask; and

a mandrel metal route provided in a recess formed by etching a portion of the hardmask formerly covered by one of the first mandrels and a non-metal route is formed in a recess formed by etching the hardmask in one of the first non-mandrel regions.

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